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Some Problems of the Stratosphere

Przegląd Meteorologiczny i
Hydrologiczny, Remuald Guminski;
Warsaw: No. 2-4 (December 1948), pp 11-20.

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SOME PROBLEMS OF THE STRATOSPHERE

(with 7 plates)

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*See also, the part
of the original
figure, which is the
best.*

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The distinguished French meteorologist, Teisserenc de Bort was puzzled and disquieted by the results he obtained while conducting soundings of the atmosphere in the last decade of the past century. Light weight measuring instruments conveyed aloft by means of paper balloons, recorded evidence of an astonishing phenomenon: at a height of 10 to 11 kilometers the temperature of the air not only ceased to fall as the balloon continued to rise. At times even began to increase slightly. Teisserenc de Bort formed two hypotheses: (1) either the apparatus ceases to function because of those heights; or (2) with the small amount of circulation resulting from a decrease in the vertical velocity of the balloon, excessively high temperatures result because of the influence of solar radiation. With this idea in mind, he made several night soundings at the Observatory in Trappes in order to eliminate the supposed influence of radiation. The result, however, was the same; at a height of 10 to 11 kilometers the temperature stopped falling. Teisserenc de Bort hesitated a while longer and finally decided to publish his observations. He did this in "Comptes Rendus" the printed publication of the Paris Academy of Science. His work appeared on 26 April 1902.

Exactly three days later, on 1 May 1902, the German meteorologist Assmann notified the Berlin Academy of Sciences of his soundings in the atmosphere. In his note he stated the same results as had Teisserenc de Bort.

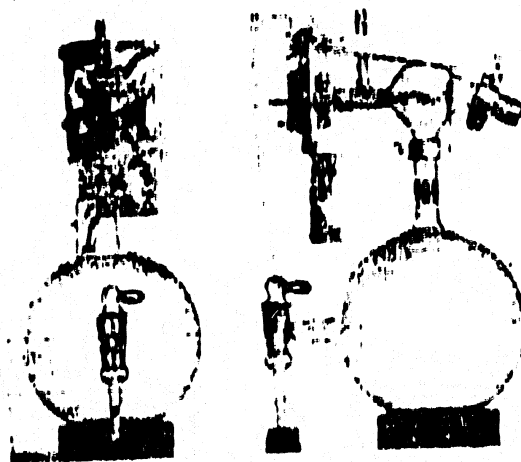
The stratosphere was opened.

Although much research has been done since that time,

although many scientific works have been published concerning the structure and makeup of the atmosphere we unfortunately still have a great many gaps in our knowledge of the stratosphere. Many phenomena still puzzle us. Many problems still have to be untangled.

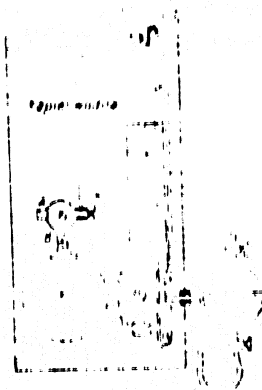
It might seem that the problems of the stratosphere interest only the representatives of pure science and have no practical significance. But the rapid pace of contemporary living and the unprecedented development of technology have unified these problems into the sphere of applied research. There arose, for instance, the question of whether it might be possible to make flights into the stratosphere. Pilots of this level, from the point of view of low wind resistance would be less costly and more economical. We may find the answers to these questions when certain physical conditions of the stratosphere have been explained; more precisely: physical conditions at a height of 10 to 20 kilometers above the surface of the earth. Something of this sort has been done in recent years in many research experiments, most of all in Germany. In this article I should like to discuss some of the results of the research conducted by the German meteorologist, Rechner, in 1939 and 1940 -- which never became public knowledge. (It was printed only in a secret publication of the German Academy of Aviation Research (Deutsche Akademie der Luftfahrtforschung).)

The first of these problems is that dealing with the oxygen content in the upper strata of the atmosphere. The concern here is not so much the oxygen necessary for breathing as the oxygen needed in order for the airplane motors to work,



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Figure 123

Figure 123

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because their functioning is affected by the change in quantity of this element in the atmosphere. A low oxygen content in the ^{upper} ~~lower~~ strata undoubtedly complicates flying conditions for stratosphere aeronautics.

Regener used the following method in his research on the oxygen content of the stratosphere.

He released a large, three-litre glass flask (Figures 1 and 2) with the aid of sounding balloons. Before the flask was released the air was carefully pumped out of it. At the determined height an appropriately arranged aneroid engaged an electromagnet which opened a cock on the flask for an interval of 1/2 to 1 minute and when the flask had filled with air the cock closed. The cock was sealed with grease. The flask was released in cellophane gondolas which let through direct solar radiation but did not emit radiation. This allowed the apparatus to be kept at a temperature of around plus 20 degrees even at a height in the stratosphere where the temperature was from minus 50 to minus 60 degrees.

Figure 3. Water Bath

The determination of the oxygen content was effected by use of the apparatus shown in ~~the~~ drawing (Figure 3). As can be seen, it was not necessary to empty the flask. The flask containing the specimen of air was put into a water bath and connected to the tube of a barometer. The oxygen was reduced with the aid of nearly redhot copper. Reducing the oxygen lowered the air pressure which could be measured with the barometer. Before being measured, volume of each air specimen was

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reduced by comparison.

The results of the computations are given in the table below.

Day	Altitude (km)	Oxygen Content (Percent)	Now indicated in Figure 4
12/5/35	18.5	20.84	cross
"	22.2	20.57	cross
12/1/35	14.5	20.89	triangle
2/12/35	24.0	20.7	triangle
5/6/36	28.5	20.39	star
8/10/36	19.5	20.88	circle
8/24/36	0	20.93	circle
9/5/36	14.0	20.90	circle
9/5/36	16.3	20.85	circle
9/5/36	17.3	20.81	circle
10/13/36	24.0	20.73	circle

As may be seen a decrease in oxygen content takes place in the upper strata of the atmosphere but it is not large. At an altitude of 16 to 18 kilometers the decrease is a few hundredths of one percent, and only at 20 kilometers does it amount to a little more -- a few tenths of one percent. At an altitude of approximately 30 kilometers the decrease in oxygen approaches 0.5 to 0.6 percent of the oxygen content in the lower strata of the atmosphere. Percentages are given here

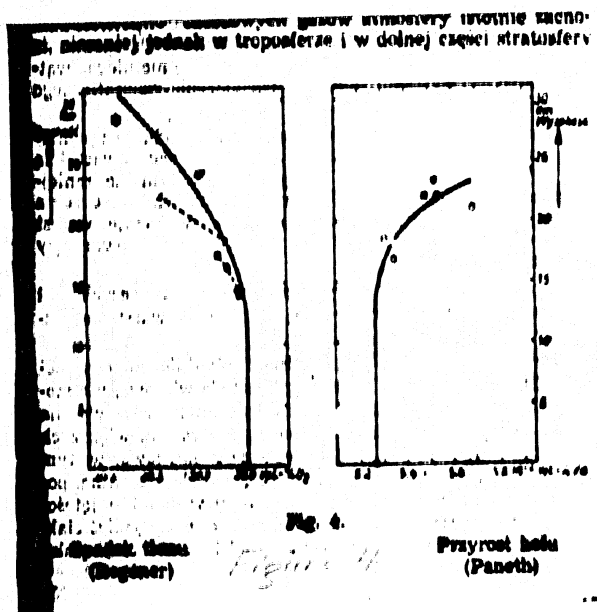
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in proportion to 100 parts of air. Computing in proportion to the oxygen alone the decrease in that element at an altitude of 30 kilometers amounts to about 3 percent of the amount of oxygen in the lower strata of the air.

The decrease in oxygen is indicated by the graph in Figure 4. The diagram is based on data from many soundings, that is, many flasks were released one after another in individual soundings in order to obtain data on the amount of oxygen under the same meteorological conditions but at varying altitudes.

It is known that if several gases are confined in one and the same area, the pressure of the gaseous mixture equals the sum of the partial pressures of the individual gases in the mixture. Partial pressure is that pressure which would exist if, other conditions being constant, one gas itself occupied the space which is occupied by the mixture. Until recently it was believed that in the atmosphere water vapor and gases existing in admixtures ~~are~~ ^{can} ~~not~~ ^{be} ~~considered~~ ^{to exist in} a condition of diffuse equilibrium ~~exists~~; that is each constituent gas forms to a certain extent in an independent atmosphere and in each of these atmospheres the density decreases differently together with the altitude; in heavy gases more rapidly, in light gases more slowly. In other words, the content of heavy gases (CO₂) is greatest when there is a decrease in altitude, while the content of lighter gases (hydrogen, helium) is greatest when there is an increase.

Regener's research shows that whatever the theoretical



Handwritten notes:

1. Wzrost temperatury w troposferze i w dolnej części stratosfery.

2. Zmiany gęstości atmosfery i inne warunki atmosferyczne.

"distribution" of constituent gases in the atmosphere may really be, nevertheless in the troposphere and in the lower parts of the stratosphere there exists, to an extent relatively unknown, a convection equilibrium, that is, the mixing of air in a vertical direction.

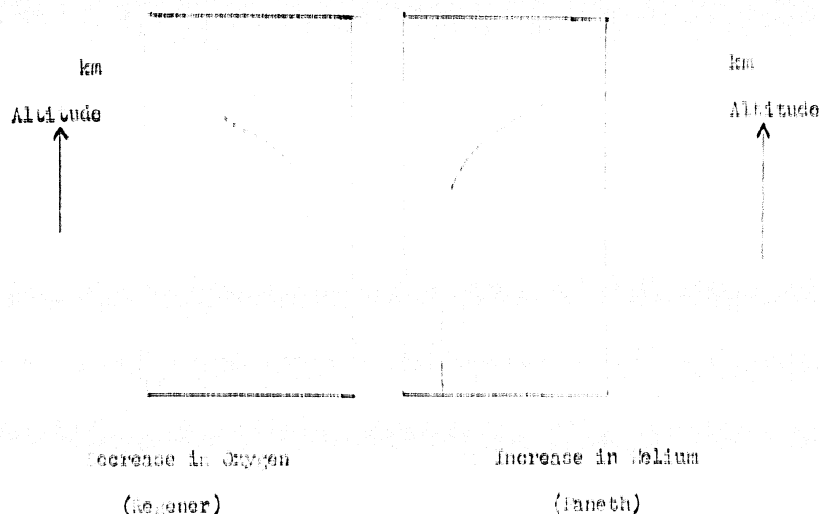


Figure 4 [Note: Thermoprint of original also given.]

One interesting detail in Figure 4 deserves attention. The decrease in oxygen as shown by measurements taken on 5 December 1935 is clearly more abrupt than that shown by another measurement. On that day the sounding was taken in masses of polar sea air. This leads us to the hypothesis that the decrease in oxygen depends on the latitude. Since the troposphere extends higher in the equatorial zone, because the movements of air caused by solar radiation are considerably intense, and

therefore the mixing process extends to considerably higher altitudes than in the polar regions, the decrease in oxygen in these zones will be slower than it will be in the polar regions. The curve x-----x obtained by Regener in masses of polar air supports this hypothesis. Although this may not be shown clearly by all of his soundings, it does seem beyond a doubt that the decrease in oxygen depends on geographic location of the sampling.

Regener's measurements show an interesting conformity to those obtained by the Englishman Lancelotti concerning the helium content in the atmosphere. This conformity is illustrated by the fact that at approximately the same altitude at which Regener's curve indicates a decrease in oxygen, Lancelotti's curve indicates an increase in helium; therefore a decrease of a heavier gas in the atmosphere is accompanied by an increase of a lighter gas.

Another problem with which Regener was concerned was the problem of the water vapor content in the upper strata of the atmosphere.

He immediately met with difficulty as to the method of measurement. The hair method usually used in serology could not be used because, as a result of desensitization, the hair hygrometer does not function at high altitudes (higher than 7 kilometers). For this reason Regener worked out a somewhat more complicated but accurate method arbitrarily based on the assumption that the water vapor content in a given volume of air is determined by passing the air through some hygroscopic substance for absorption, and weighing that substance before

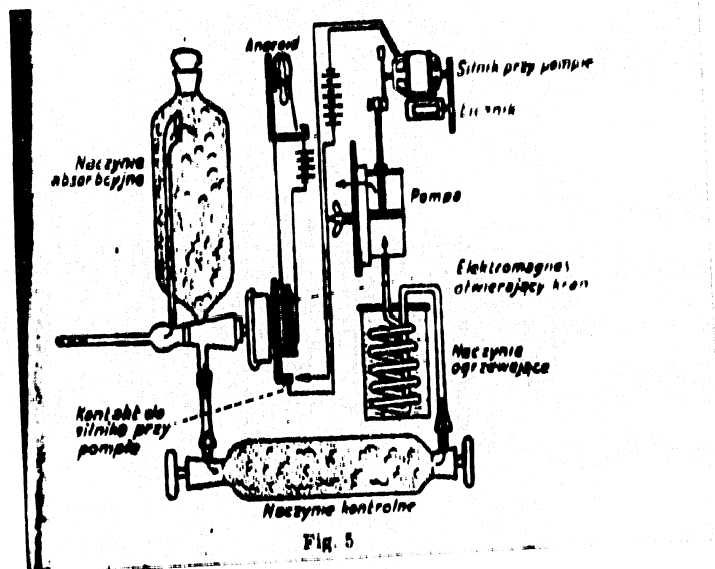


Fig. 5. Schemat układu pomiarowego.

and after absorption. The absorbing substances used was phosphorous pentoxide (P_2O_5).

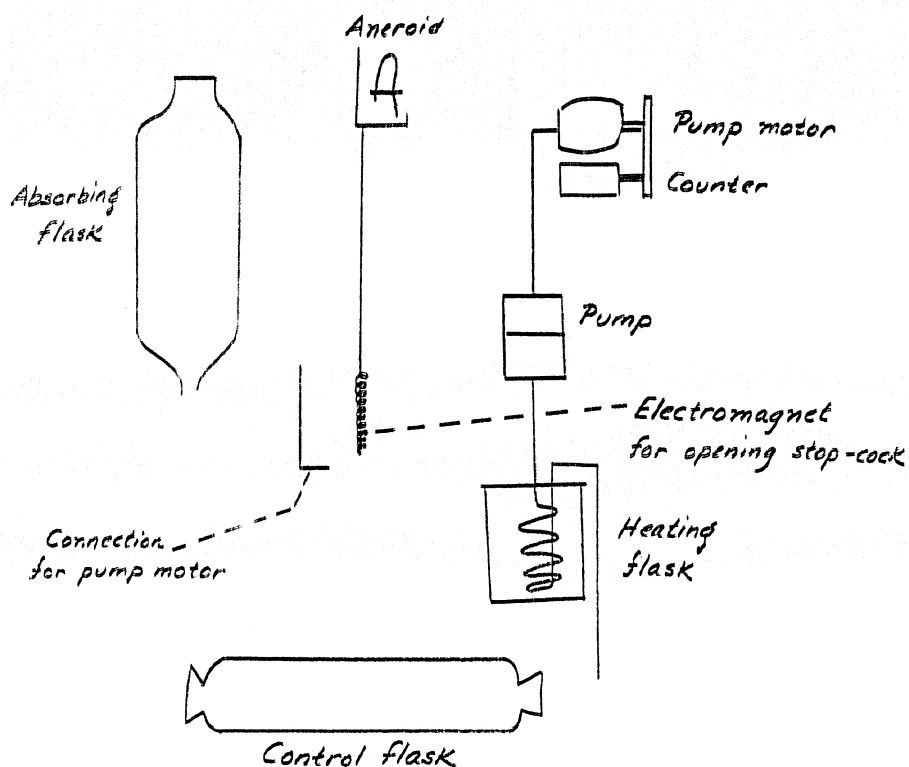


Figure 5. [Note: Thermoprint of original given.]

Figure 5 is a drawing of the apparatus used in this experiment. With the aid of an aneroid operating on an electromagnet the absorbing flasks are opened at the indicated height at which the measuring is to take place. There are usually three of these flasks (only one is shown in Figure 5), and therefore measurements at three heights can be taken at the same time. The aneroid, in opening the cock to the absorbing flask by means of

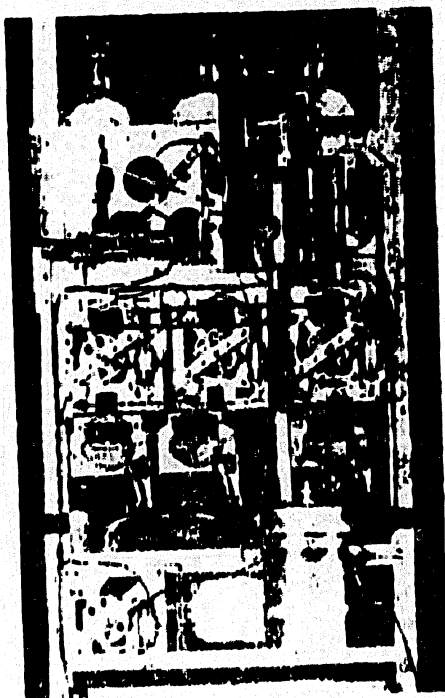


Figure 6

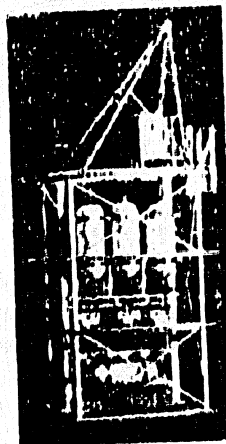


Fig 7

Figure 7

an electromagnet, simultaneously starts a pump, whose strokes are counted by a special counter. After the number of strokes is determined, through similar contact the pump is stopped and the absorbing flask closed. In order to determine with relative accuracy the amount of air pumped in, in front of the pump a beaker is set up containing a coil in which the air is heated to a definite temperature; a control flask is also set up and it serves as a check to see whether complete absorption of the water vapor has taken place in the given absorption flask. The absorbing flasks were, of course, weighed before and after the measurements. Figure 6 and 7 are two photographs of the apparatus minus the securing gondola. In order to determine both the absolute and relative humidity, a thermograph (put beside the gondola for protection) was released along with the apparatus. The thermograph was enclosed in a powerful ventilator which, however, worked only when the pump operated.

The results obtained from the humidity readings are given in Table 2 below. From it we see that on the whole the amounts of moisture in the air in the stratosphere are small. The comparatively high relative humidity on 8 July 1938, at an altitude of 10 1/2 kilometers is immediately obvious (58 percent in relation to ice ~~etc.~~). A somewhat higher humidity was shown by the sounding obtained on 19 July 1939, at more or less the same altitude.

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Date	Altitude km	Temperature C°	Relative humidity
			(in relation to ice) Percent
5/1/38	7	22	16.7
7/8/38	7	19.8	26
"	10.5	41.8	58
"	16	43.7	18
11/-/38	7.5	35	44
2/15/39	7	23.5	42
"	10.5	34.5	39
12/19/39	7.7	24.5	16
"	10.6	49	59
"	22.2	47	7

As can be seen, the values of relative humidity obtained are comparatively low (they do not reach 60 percent in relation to ice ~~at 7°~~). We know, however, that states of supersaturation can exist in the stratosphere under certain conditions. This is indicated by the presence of so-called nacreous clouds, which are very iridescent, and therefore are formed from delicate ice crystals. These clouds are often observed in Scandinavia in times of weather depression. The well-known Norwegian investigator, Störmer, established, with the aid of an accurate method of photography, that the altitude at which they are usually observed fluctuates between 23 to 26 kilometers.

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Regener's method of measuring humidity is without doubt very interesting and original, but it is so complex that unfortunately it cannot be used for systematic measurements on a larger scale, that is, at a greater number of points.

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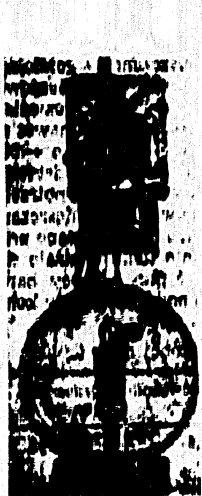


Fig. 1

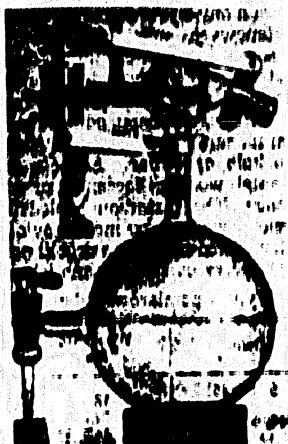


Fig. 2

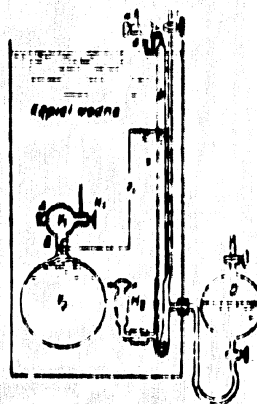


Fig. 3

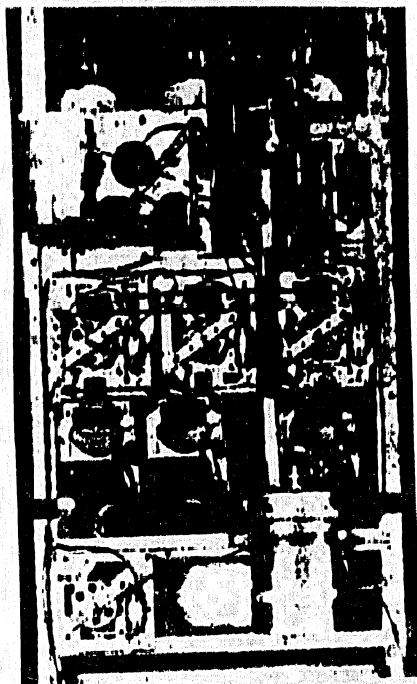


Fig. 4

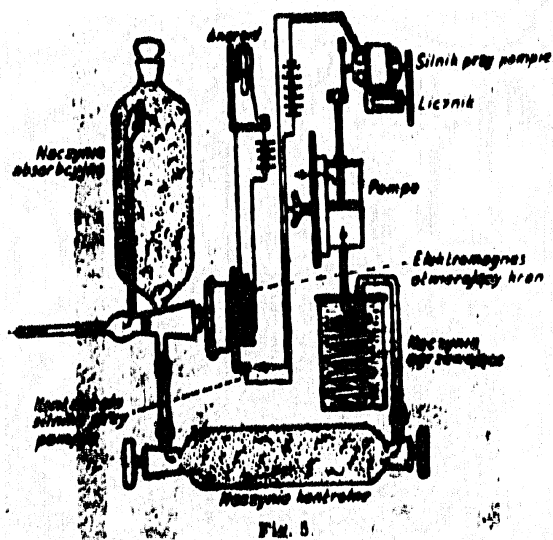


Fig. 5

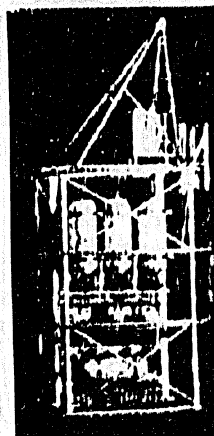


Fig. 6